U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Fire Research at the United States Nuclear Regulatory Commission

Federal Fire Research Telecom
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Mark Henry Salley, P.E.
Branch Chief, Fire Research Branch

Office of Nuclear Regulatory Research

Overview of the Fire Hazard to Nuclear Power Plant (NPP)

- **Fire is NOT a Design Basis Accident (DBA)**
  - WASH-1400 (1975)
    - Potential core melt ~ 20% of all other causes analyzed
  - NUREG-0800 (R2, 1981)
    - On average, a NPP will experience one or more fires of varying severity during its operating life. (Note: Data bases used for PRA suggest on the order of one per ten reactor-years operation)
  - NUREG-1742 (2002)
    - Fire-induced Core Damage Frequency (CDF) range from 4E-8 to 2 E-4 per reactor year, majority lie between 1E-6 to 1E-4
    - Most NPP report that fire-induced CDF exceeds 10% of internal events CDF
    - About 25% NPP report that fire-induced CDF exceeds corresponding internal events CDF

Nuclear Power Plant Fire Protection Rules

- **Fire Protection Rule:**
  - 10 CFR 50.48
    - 10 CFR 50 Appendix A General Design Criteria - Criterion 3
    - 10 CFR 50 Appendix R
- NFPA 805 Risk-Informed Performance Based Fire Protection
  - Voluntary Rule
    - Approximately ½ Industry is transitioning
    - Sheron Harris is 1st NPP to transition

General NPP Fire Protection

- Plant-wide Fire Protection
  - Addresses all areas of the Nuclear Power Plant (NPP)
  - Based on Defense-In-Depth (DID)
    - Fire Prevention
    - Early Detection & Rapid Suppression
    - Design Features to protect essential NPP safety functions
  - Requires a Fire Hazard Analysis (FHA)
  - Reactor Post-Fire Safe-Shutdown

Fire Research at the NRC

- Office of Nuclear Regulatory Research (RES) is one of the Major NRC Offices
  - 3 Divisions
  - 15 Branches
  - Approximately 220 Engineers, Scientists, support staff.

Overview of NRC RES Activities

- Mainly “Applied Research”
- Continue to Advance the Science and Understanding
  - Develop Methods, Tools, and Data
  - Improve the State-of-the-Art
  - Expand the Knowledge Base
- Reduce Uncertainty
  - Continue to refine/improve
    - Methods Tools
    - Data

Research Partners

- Electric Power and Research Institute (EPRI)
  - Memorandum of Understanding (MOU)
- National Institute of Standards and Technology (NIST)
  - Fire Modeling and Experiments
- Department of Energy (DOE) Laboratories
  - Sandia, Brookhaven, Idaho
- International Partners
  - MOU with Japan
  - OECD
- Academic
  - University of Maryland

Fire Modeling

- NUREG-1805 “Fire Dynamic Tools”
  - Initial Issue: December 2004
- New Chapter “THIEF Model”
  - Developed as a part of CAROLFIRE
- New Look to Spreadsheets
  - Update/correct errors
- NUREG-1805 Supplement 1
  - Issue Summer 2013

Fire Modeling (cont.)

- NUREG-1824 EPRI-1011999 V&V
  - Initial Issue: May 2007
  - Future Expansion currently in Progress
- NUREG/CR-6978 Phenomena Identification and Ranking Table (PIRT)
  - Initial Issue: November 2008
- NUREG-1934 EPRI-1023259 NPP Fire Modeling Analysis Guidelines
  - Issue November 2012

CHRISTIFIRE

CHRISTIFIRE

- Cable Heat Release Ignition, and Spread in Tray Installations During FIRE (CHRISTIFIRE)
- Better Understanding Cable Tray Fires
  - Heat Release Rate (HRR)
  - Ignition
  - Flame Spread
- Multiple Phase Project
  - NIST Performing the Experiments
- Significantly Advances the Science
  - Revise NUREG/CR-6850 Appendix R
- NUREG/CR-7010 Vol. 1 issued July, 2012
  - Vol. 2 issued
  - Vol 3 currently in development

CHRISTIFIRE (continued)

- Next Phases address variables such as:
  - Cable Orientation
  - Fire Retardant Coatings
  - Cable Tray Covers
  - Wind Aided Flame Spread

CHRISTIFIRE

CHRISTIFIRE

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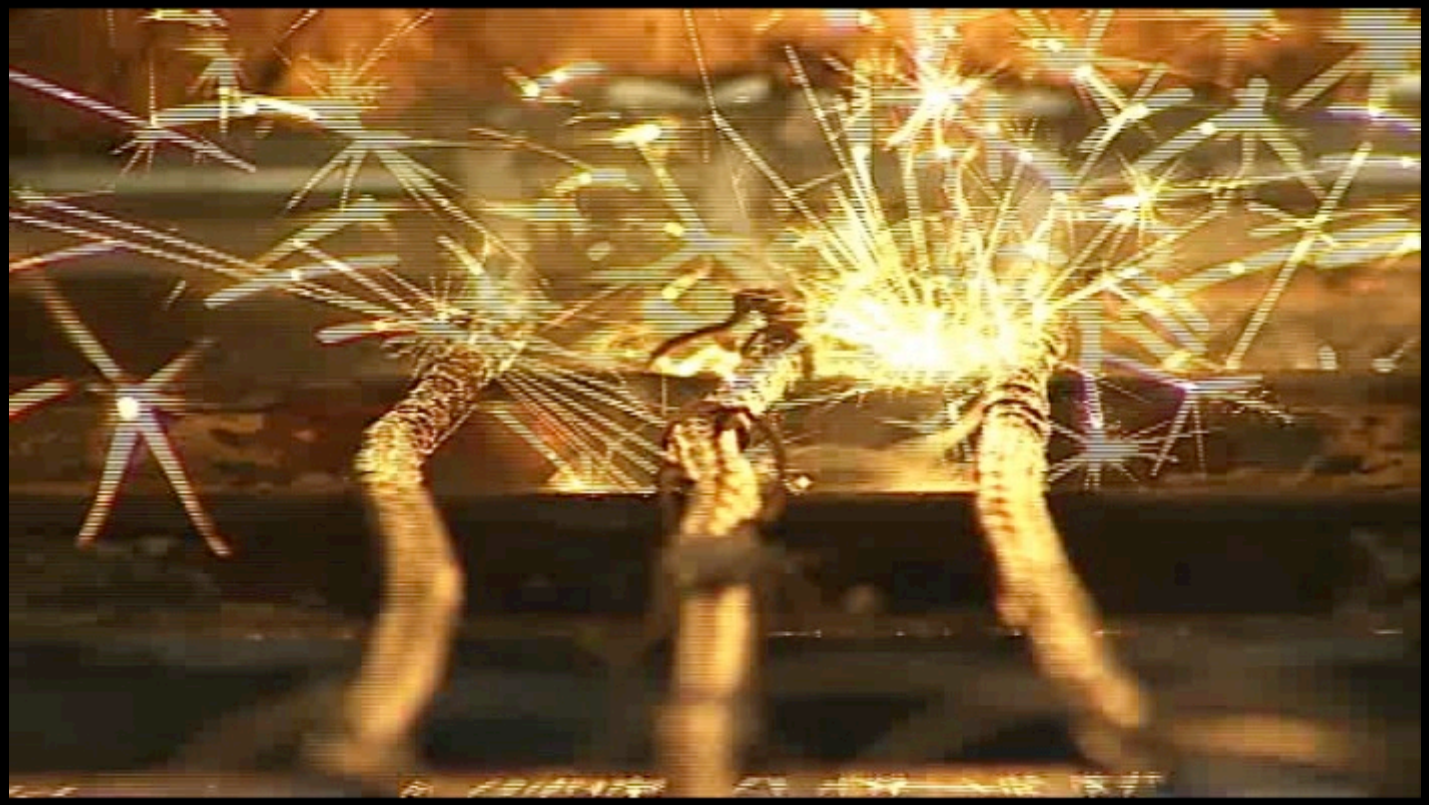
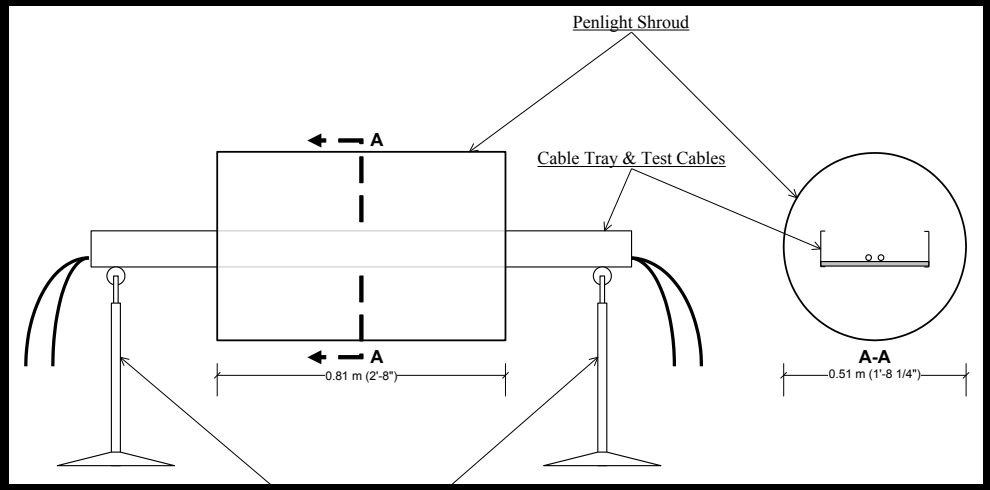
DESIREE-FIRE

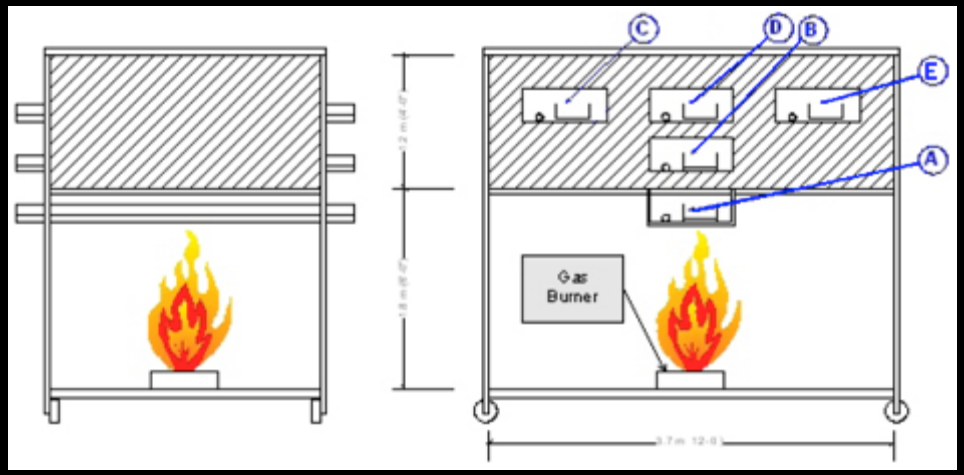


Testing for Further Refinements

- Direct Current Electrical Shorting in Response to Exposure Fire (DESIREE-FIRE)
- To Better Understand the differences between alternating current (ac) and direct current (dc) circuit response
- Supports NFPA 805 and Appendix R Analysis
- Numerous safety related systems commonly powered with dc
- DESIREE-Fire NUREG/CR-7100 issued April 2012

- Small-Scale
  - 59 tests
  - 1 circuit type per test





- Intermediate-Scale
  - 16 tests
  - Every circuit per test

DC Test Results

- Open Circuits
- Energetic faults

DC Hot Short

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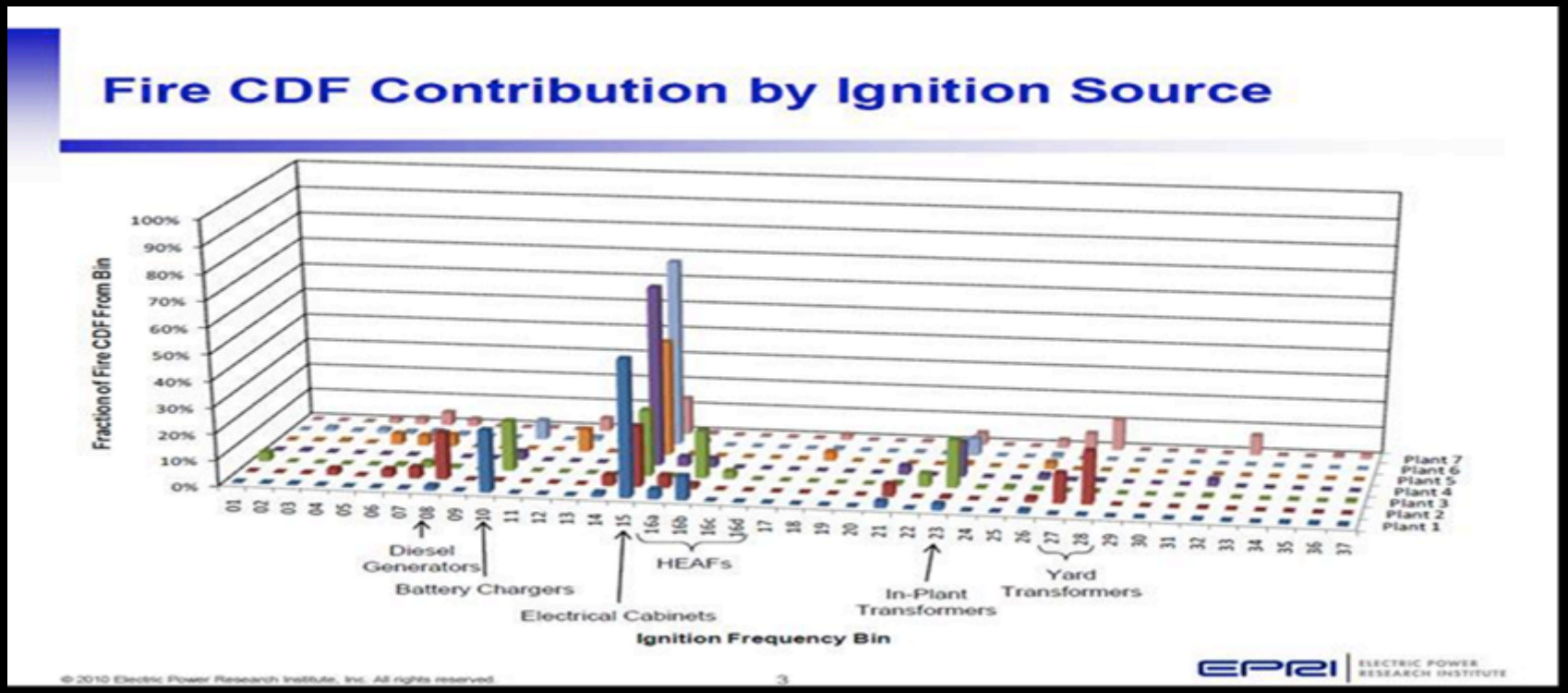
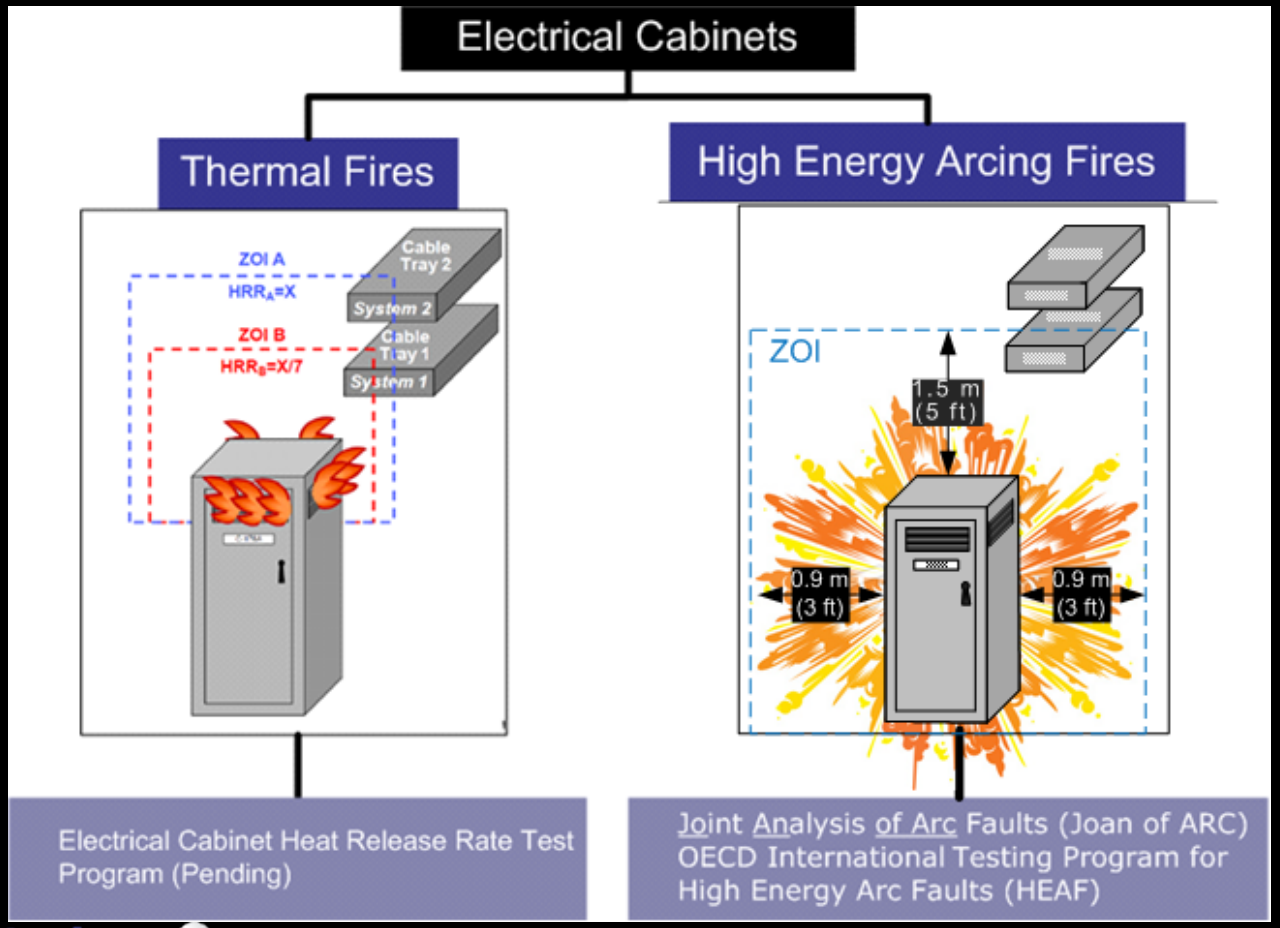
Electrical Enclosures- PRA Insights



Electrical Enclosures- Failure Modes



High Energy Arc Fault (HEAF)

- Fire PRA are demonstrating major risk to Reactor Safety comes from electrical enclosures failing (Switchgear, Breakers, etc.)
  - Classic Fire HRR
  - HEAF
- March 11, 2011, Onagawa NPP Japan experienced a Seismic Induced HEAF

HEAF (continued)

- NRC leading an International Testing Program with OECD
  - Joint Analysis of Arc Faults (JOAN OF ARC)
    - Approximately 10% International NPP Significant Fire Experience are HEAF
  - Testing to be Performed in 2014 and 2015
  - What to Measure?
  - How to Measure it?

HEAF Test Video

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HEAF Video and IR

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HEAF Progression

HEAF Events in US NPPs

Waterford
1995

Diablo Canyon
2000

Prairie Island
2001

Robinson 2010

Columbia 2009

SONGS 2001

NUREG/CR-6850

Fire PRA Training

- Based on NUREG/CR-6850 (EPRI1011989)
- Currently 5 Separate Classes
  - Fire Probabilistic Risk Analysis (PRA)
  - Fire Analysis (Basic Fire Dynamics)
  - Electrical Circuit Analysis
  - Fire Human Reliability Analysis (HRA)
  - Advanced Fire Modeling
- Federal Register Notice attached with dates and locations for 2015
- https://custom.cvent.com/0C2B71276B454075AA018365A85CB80E/files/Event/98d9f59e06f847c5a88be66eec6e1587/988da72cf6cc4f04be9f97ae4ad018e8.pdf

Knowledge Management

- NRC is now 40 years old
  - New Generation of Safety Professionals
- Need to retain the agency's knowledge to pass on
  - NUREG/KM-0001 Three Mile Island Accident
  - NUREG/KM-0002 Browns Ferry Fire
  - NUREG/KM-0003 Fire Protection Community of Practice
  - NUREG/KM-0005 Davis Besse Corrosion
  - Others in the works
    - Chernobyl
    - Hydrogen

Questions?